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Original Article

Prevalence and course of lower limb disease activity and walking disability over the first 5 years of juvenile idiopathic arthritis: results from the childhood arthritis prospective study

Gordon J. Hendry¹, Stephanie J. Shoop-Worrall², Jody L. Riskowski¹, Pamela Andrews¹, Eileen Baildam³, Alice Chieng⁴, Joyce Davidson^{5,6}, Yiannis Ioannou⁷, Flora McErlane^{8,9}, Lucy R. Wedderburn^{10,11,12,13}, Kimme Hyrich^{2,14,15}, Wendy Thomson^{2,16} and Martijn Steultjens¹

Abstract

Objective. The aim was to investigate the time course of lower limb disease activity and walking disability in children with JIA over a 5-year course.

Methods. The Childhood Arthritis Prospective Study is a longitudinal study of children with a new JIA diagnosis. Childhood Arthritis Prospective Study data include demographics and core outcome variables at baseline, 6 months and yearly thereafter. Prevalence and transition rates from baseline to 5 years were obtained for active and limited joint counts at the hip, knee, ankle and foot joints; and walking disability, measured using the Childhood Health Assessment Questionnaire walking subscale. Missing data were accounted for using multiple imputation.

Results. A total of 1041 children (64% female), with a median age of 7.7 years at first visit, were included. Baseline knee and ankle synovitis prevalence was 71 and 34%, respectively, decreasing to 8–20 and 6–12%, respectively, after 1 year. Baseline hip and foot synovitis prevalence was <11%, decreasing to <5% after 6 months. At least mild walking disability was present in 52% at baseline, stabilizing at 25–30% after 1 year.

Conclusion. Lower limb synovitis and walking disability are relatively common around the time of initial presentation in children and young people with JIA. Mild to moderate walking disability persisted in ~25% of patients for the duration of the study, despite a significant reduction in the frequency of lower limb synovitis. This suggests that there is an unmet need for non-medical strategies designed to prevent and/or resolve persistent walking disability in JIA.

Key words: juvenile idiopathic arthritis, epidemiology, lower limb, ankle, foot, knee, hip, synovitis, walking disability, prevalence

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Key messages

- Prognosis for lower limb disease is good, but walking disability persists for many with JIA.
- There may be unmet need for care to prevent and/or resolve walking disability in JIA.
- Evidence is provided for walking disability trajectories including absence, persistent moderate and fluctuating courses.

Introduction

JIA is the most common form of inflammatory arthritis in childhood, with an estimated prevalence of 1 per 1000 children [1]. In JIA, synovitis is the primary disease pathology, and its clinical signs and symptoms include joint pain, swelling, stiffness and deformities [2–4].

JIA has a predilection for involvement of the lower limb joints, particularly the knee and ankle [5–7]. Lower limb synovitis has been associated with abnormal function in several small-sample cross-sectional studies of gait and clinical surveys [2, 8–10]. Results from these studies suggest that some children with JIA have degraded gait patterns characterized by decreased walking speed and step length and altered loading characteristics [2, 8, 10]. Such impairments typically manifest as difficulties with undertaking routine functional tasks, including walking and stair climbing. Walking is the most common form of incidental, free-living physical activity in children and adolescents [11]; therefore, further research on the long-term impact of lower limb disease on walking ability in JIA is warranted.

Only one study evaluated the long-term prevalence and course of lower limb disease activity in children with JIA [5]. It was found that almost all children with JIA will experience lower limb joint synovitis at some point over the course of their disease [5]. Early in the post-diagnosis stage, ~75 and ~60% of those with JIA will experience knee or ankle joint synovitis, respectively, decreasing to 50% at 1 year post-diagnosis with the introduction of first-line disease-modifying therapies, and 30–40% thereafter [5]. Impairments in physical function, such as walking disability, associated with lower limb synovitis [2, 9, 12, 13] were not evaluated.

Composite measures of disease activity are considered potentially to be reversible with appropriate pharmacological therapies [14, 15]. In contrast, outcome measures for the physical function domain incorporate both reversible and irreversible components [3, 16]. Functional disability scores appear to be highly correlated with active joint counts in early disease, whereas limited joints counts are highly correlated with disability and radiographic joint damage with longer disease durations [3, 16]. These findings suggest that some children with JIA might be vulnerable to a persistent or progressive course of disability, despite suppression of disease activity.

Relative to the prevalence and course of general disability in JIA, which has been well described [3, 16], walking disability has not been studied. Greater

understanding of the patterns of lower limb joint impairments and how they relate to walking disability over time might facilitate more effective rehabilitative management strategies. The objectives of the present study were to investigate the prevalence and time course of lower limb disease activity and walking disability in patients with JIA over the first 5 years after diagnosis and to identify walking disability trajectories over this 5-year course.

Methods**Study population**

Participants in this study are from the Childhood Arthritis Prospective Study (CAPS), with details of the study described elsewhere [17]. In short, CAPS is a multicentre study in the UK that commenced in 2001, to identify predictors of short-term and long-term outcomes of inflammatory arthritis. CAPS participants were children (aged ≤16 years at onset) with inflammatory arthritis of at least one joint persisting for ≥2 weeks, who were recruited after first presentation to paediatric rheumatology. Exclusion criteria are septic arthritis, haemarthrosis, arthritis caused by malignancy, trauma or connective tissue disorders. CAPS complied with the Declaration of Helsinki and was approved by the North-West Multi-Centre Research Ethics Committee. Written informed consent was obtained from the parent(s)/guardian for participating children, and children considered able provided age-appropriate assent.

Data collection

At baseline, the rheumatologist clinically examined the joints, recording the number of limited and active joints (out of 71 joints), completed a 10 cm physician's global assessment (PGA) visual analog scale (range 0–10 cm, where 10 is the worst score) and assigned an ILAR subtype of JIA based on the disease characteristics at presentation [18]. A joint was considered active if there was swelling attributable to active synovitis or, in the absence of swelling, limited motion accompanied by heat, pain or tenderness [19]. A limited joint was a joint limited in motion. The parents and child were interviewed by a rheumatology research nurse, and medical records were reviewed to extract data on demographics. The parent or child, where appropriate, completed the childhood health assessment questionnaire (CHAQ), a measure of functional disability (range 0–3, where 3 is the worst)

[20], a 100-mm visual analog scale pain scale, and a 10-cm parent/patient global health measure [parent general evaluation (PGE)]. The CHAQ was completed by the parent if the child was ≤ 10 years old or optionally by the parent or child if aged ≥ 11 years. The active joint count, PGA and PGE were used to calculate the clinical juvenile arthritis disease activity score based on a 27-joint count (which excludes ESR) [14].

CAPS follow-up data collection

Follow-up study data were captured at 6 months after first presentation and then annually for 5 years. Data were extracted from the medical record and included the most recent rheumatological examination, PGA, PGE, CHAQ and pain visual analog scale.

Statistical analysis

Patient data between 2001 and December 2015 were available for analysis. This analysis was limited to children who presented to paediatric rheumatology before September 2010, who were diagnosed with JIA [18], and who had both active and limited joint counts recorded and/or had completed the CHAQ on at least one occasion over a 5-year follow-up period.

Demographic and disease characteristics (active and limited joint count, PGA, PGE, CHAQ score, excluding ESR), pain, clinical juvenile arthritis disease activity score based on a 27-joint count and ILAR subtype as recorded at 1 year were summarized using descriptive statistics.

Local joint impairments were determined using active and limited joint counts recorded at the hip, knee, ankle, subtalar, inter-tarsal, MTP and IP joints and dichotomized as present (at least one limb affected) or absent (0). Walking disability was measured using the CHAQ walking subscale [Is your child able to: (1) walk outside on flat ground, and (2) climb up five steps? Possible responses include: without any difficulty, with some difficulty, with much difficulty, or unable to do.]. CHAQ walking disability is reported in terms of severity (0 = no disability, 1 = mild disability, 2 = moderate disability, 3 = severe disability), as well as present (≥ 1 , at least mild disability) or absent (0, no disability). The prevalence of lower limb synovitis and walking disability and the severity of walking disability were calculated as absolute frequencies (n) and percentages (%) of participants. Change between consecutive follow-ups was calculated as percentages of participants with new, stable or resolved synovitis (knee and ankle joints only) and walking disability. Analyses were undertaken using SPSS 22 (IBM SPSS Statistics for Windows, version 22.0; IBM, Armonk, NY, USA) and STATA 13 (Stata Statistical Software, release 13; StataCorp LP, College Station, TX, USA).

Analyses of prevalence for active lower limb joints assumed that some data were missing-not-at-random. Children with missing data were split into seven groups: those discharged well, transferred to other clinics (excluding those who have probably moved to adult services), transferred to adult services, moved home

address, lost to follow-up in CAPS, follow-up completed but with incomplete data, and follow-up missed but with subsequent return to follow-up. Assumptions were made regarding these groups based upon the approach by Shoop-Worrall *et al.* [21]: participants had no active lower limb joints at follow-up if they belonged to groups one, three, five and seven. All other data were assumed to be missing-at-random and were imputed via multiple imputation over 20 iterations using STATA 13. Missing data for prevalence of limited joints and walking disability were all assumed to be missing-at-random and thus were imputed via multiple imputation over 20 iterations (see [Supplementary Data](#), section Methods for handling missing data, available at *Rheumatology Advances in Practice* online). Multiple imputations were not undertaken where the observed prevalence for individual affected joints was low ($< 5\%$ at follow-up). Secondary analyses included graphical explorations of complete (referred to as closed cohort), incomplete (open cohort) and imputed case analyses for active/limited joints and presence/absence of walking disability (see [Supplementary Figs S1–8](#), available at *Rheumatology Advances in Practice* online).

Transition rates for walking disability states for the entire sample between follow-ups were explored using the TraMineR categorical sequence data package for R [22] and are expressed as absolute frequencies and percentages. A transition is defined as the sequence of walking disability states between any two successive follow-ups (for example, an improvement from severe to moderate walking disability). Longitudinal trajectories for walking disability states from closed and open cohort data were explored graphically by constructing a riverplot using the riverplot R package.

Results

Study population

A total of 1041 children, of whom 64% were female, with a median age at baseline of 7.7 years (interquartile range 3.5–11.5 years) were included in the study (Table 1). A flowchart of study participant recruitment is provided in [Supplementary Fig. S9](#), available at *Rheumatology Advances in Practice* online.

Lower limb joint impairments

Active and limited joint counts were available for 999 children at baseline, reducing to 841 (84%) at 6 months, 916 (92%) at 1 year, 852 (85%) at 2 years, 747 (75%) at 3 years, 666 (67%) at 4 years, and 576 (58%) at 5-year follow-up. A total of 204 children had complete baseline and all subsequent follow-ups over 5 years (closed cohort). The children in the closed cohort differed significantly from the open cohort in terms of age [closed: median 5.8 (interquartile range 2.8–8.7) years; open: 8.8 (3.8–12.1) years; $P < 0.01$], symptom duration [closed: 3 (1–6) months; open: 4 (2–9) months; $P = 0.02$] and PGA [closed: 3.5 (1.8–6.1) cm; open: 2.8 (1.5–5) cm;

TABLE 1 Demographic and clinical characteristics at first presentation

Clinical features	n	Value
Age, median (IQR), years	987	7.7 (3.5–11.5)
Female, n (%)	999	642 (64.3)
Active joint count, median (IQR)	999	2 (1–5)
Limited joint count, median (IQR)	999	1 (1–3)
Physician global assessment, mean (s.d.), cm	803	3.4 (2.3)
Parent general evaluation, mean (s.d.), cm	670	2.8 (2.6)
VAS pain, mean (s.d.), mm	717	34.8 (28.3)
CHAQ score, median (IQR)	731	0.625 (0.125–1.375)
cJADAS-27, mean (s.d.)	555	10.3 (7.7)
ILAR subtype, n (%)	1033	
Systemic		53 (5.1)
Persistent oligoarthritis		457 (44.2)
Extended oligoarthritis		22 (2.1)
RF-negative polyarthritis		152 (14.7)
RF-positive polyarthritis		30 (2.9)
Enthesitis-related arthritis		54 (5.2)
PsA		70 (6.8)
Unclassifiable		195 (18.9)

Data are reported as n (%) unless otherwise stated. CHAQ: childhood health assessment questionnaire; cJADAS: clinical juvenile arthritis disease activity score; IQR: interquartile range; VAS: visual analog scale.

$P=0.01$]. For the open cohort, baseline knee joint synovitis prevalence was 71%, decreasing to 26% at 6 months and between 8 and 20% after 1 year (Fig. 1A). Baseline ankle joint synovitis was 34%, decreasing to 18% at 6 months and between 6 and 12% after 1 year. Baseline hip and foot joints synovitis prevalence was <11%, decreasing to 2–4% at 6 months and 1–3% after 1 year. Baseline limited joint prevalence at the knee was 53%, decreasing to 22% at 6 months and between 9 and 19% after 1 year (Fig. 1B). Baseline limited joint prevalence at the ankle was 21%, decreasing to 12% at 6 months and 6–8% after 1 year. Baseline limited joint prevalence at the hip and foot joints was <10%, reducing to between 2 and 6% at 6 months and ~0–5% after 1 year. Open cohort prevalence estimates were consistent with closed cohort estimates (see Supplementary Figs S1–8, available at *Rheumatology Advances in Practice* online). Imputed prevalence estimates were highly consistent (to within 2.5%) with the original data (open cohort) at each time point.

Change in active joint synovitis state between follow-ups

The hip joint remained largely quiescent between each subsequent follow-up, with >91% of participants having stable inactive hip joints, 0.5–1% having stable active disease, and 0.5–2% developing new active disease (Fig. 2A). At the knee, 23% had stable active synovitis

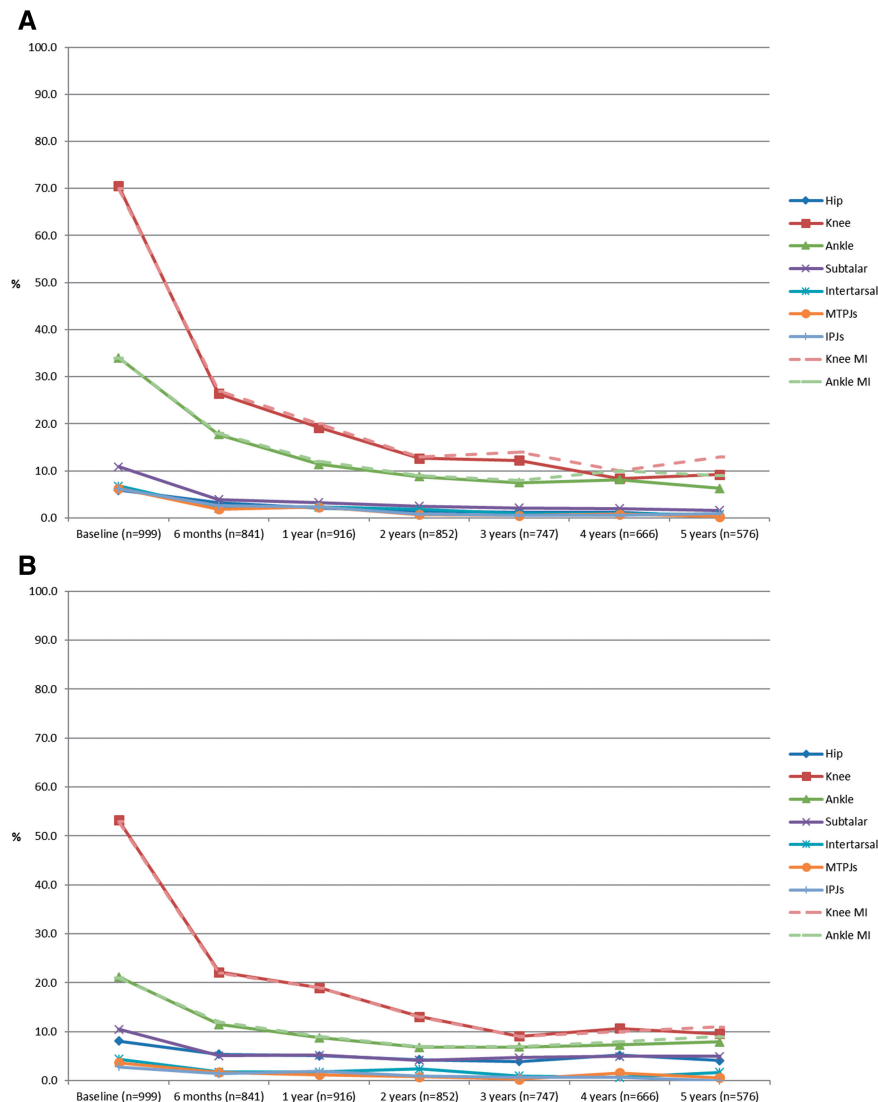
from 0 to 6 months, decreasing to 9% from 6 months to 1 year and 5–6% thereafter (Fig. 2B). New instances of knee synovitis were observed for between 7 and 12% of participants at subsequent follow-ups. After 1 year, between 70 and 75% of participants had stable inactive knee joints. At the ankle, 13% had stable active synovitis from 0 to 6 months, decreasing to 5% from 6 months to 1 year and 3–5% thereafter (Fig. 2C). New instances of ankle synovitis were observed for ~5–11% of participants at subsequent follow-ups. After 1 year, ~80% of participants had stable inactive ankle joints. The subtalar joint remained largely quiescent, with >86% of participants having stable inactive subtalar joints, 0–1.5% having stable active disease, and 2–3% developing new active disease (Fig. 2D). Imputed estimates consistently exceeded original data for inactive stable disease by up to 10%.

Walking disability

CHAQ walking disability scores were available for 737 children at baseline, reducing to 669 (91%) at 6 months, 727 (99%) at 1 year, 663 (90%) at 2 years, 592 (80%) at 3 years, 519 (70%) at 4 years, and 454 (62%) at 5-year follow-up. A total of 173 (23%) children completed baseline and all subsequent follow-ups over 5 years (closed cohort). These patients differed significantly from those with missing data for age [closed: 6.3 (2.8–10.1) years; open: 8.1 (3.8–11.9) years; $P<0.01$] and overall CHAQ score [closed: 0.5 (0.125–1.125); open: 0.75 (0.125–1.5); $P=0.01$]. For the open cohort, at least mild walking disability was present in 52% at baseline, reducing to 37% at 6 months, 33% at 1 year, and stabilizing at 25–31% thereafter. Moderate walking disability was more frequently observed at each time point relative to mild and severe walking disability (Fig. 3A), with 33% of participants having moderate walking disability at baseline, reducing to 25% at 6 months, 23% at 1 year and 17–23% thereafter. Mild walking disability was observed in 15% at baseline, reducing to 10% at 6 months, 9% at 1 year and 6–9% thereafter. Severe walking disability was relatively infrequent and was observed in 5% of participants at baseline, 2% at 6 months and <1% thereafter. Open cohort prevalence estimates were consistent with closed cohort estimates (see Supplementary Figs S1–8, available at *Rheumatology Advances in Practice* online). Imputed prevalence estimates were highly consistent (to within 1%) with the original data (open cohort) at each time point.

Change in walking disability states between follow-ups

Proportional increases were observed for participants with a stable absence of walking disability, from 41% at baseline to 6 months, to 54–67% thereafter. Stable walking disability was frequently observed, affecting 30% of participants between baseline and 6 months, decreasing to 23% between 6 months and 1 year, and between 16 and 21% thereafter. New instances of walking disability were less frequently observed, affecting between 7 and 10% of participants. Proportional decreases were

Fig. 1 Relative frequencies of active (A) and limited (B) joints, including imputed values

observed for resolution of walking disability, from 23% for baseline to 6 months, 13% at 6 months to 1 year, reducing to 7% at 4–5 years. Imputed estimates consistently exceeded original data for resolved walking disability.

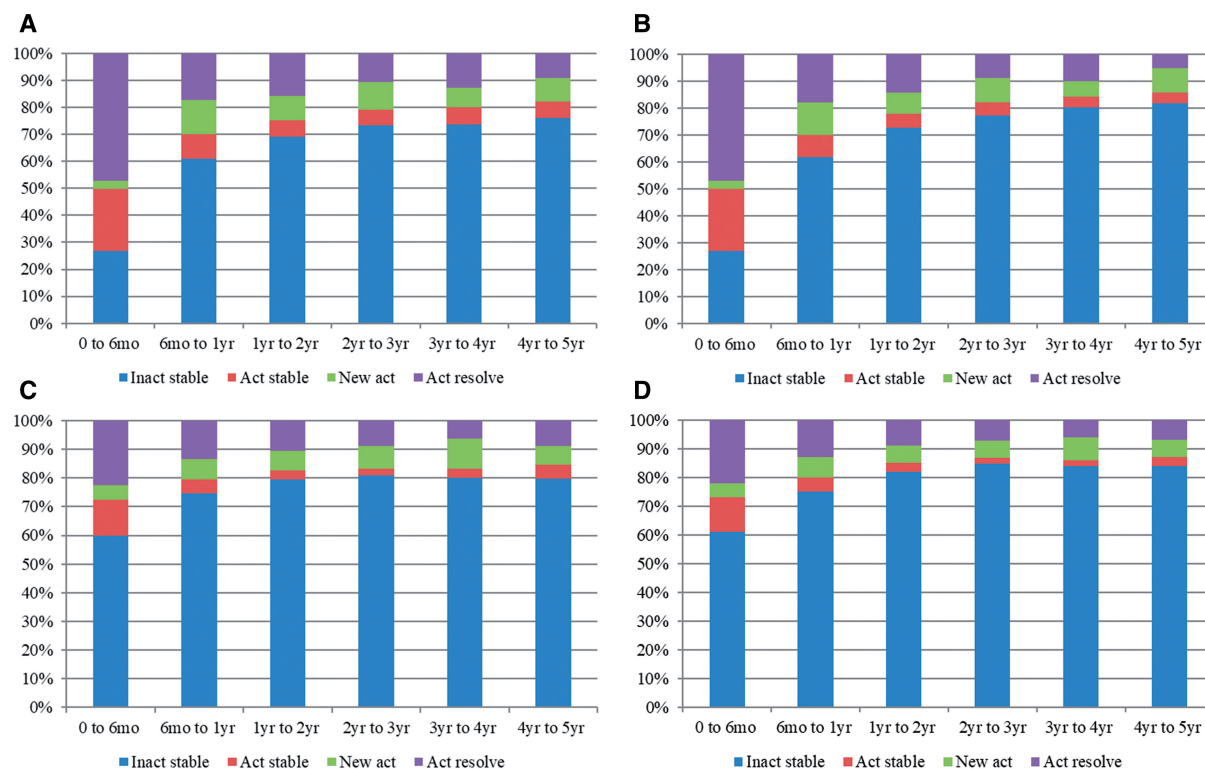
Transitions and trajectories of walking disability

For all follow-ups over the full 5-year study period there were a total of 3907 transitions for walking disability states observed for the entire sample (Table 2). The most frequently observed sequences were maintenance of no walking disability ($n=2243$, 57.4%) and maintenance of moderate walking disability ($n=518$, 13.2%) between two consecutive follow-ups. A total of 485 (12.4%) transitions were observed for at least mild walking disability to no walking disability.

The riverplots (Fig. 4A and B) reveal two main concentrations of participants, one with a stable absence of walking disability and the other with persistent moderate walking disability over 5 years of follow-up. The plots also reveals a frequent fluctuating course of walking disability, with deterioration and improvement between absent, mild and moderate walking disability states. There are also concentrations of trajectories to and from missing data to absent disability across the 5-year follow-up period (Fig. 4A).

Discussion

This study represents the first large-scale longitudinal evaluation of lower limb joint involvement and walking disability from the point of diagnosis in children with JIA.

Fig. 2 Relative frequencies for changes in disease activity

(A) Knee open cohort. (B) Knee imputed values. (C) Ankle open cohort. (D) Ankle imputed values. Dark blue: inactive stable; red: active stable; green: new active; purple: active resolved. Total *n* for closed cohort transitions between time points are as follows: 0–6 months, *n* = 819; 6 months–1 year, *n* = 734; 1–2 years, *n* = 660; 2–3 years, *n* = 521; 3–4 years, *n* = 376; 4–5 years, *n* = 274.

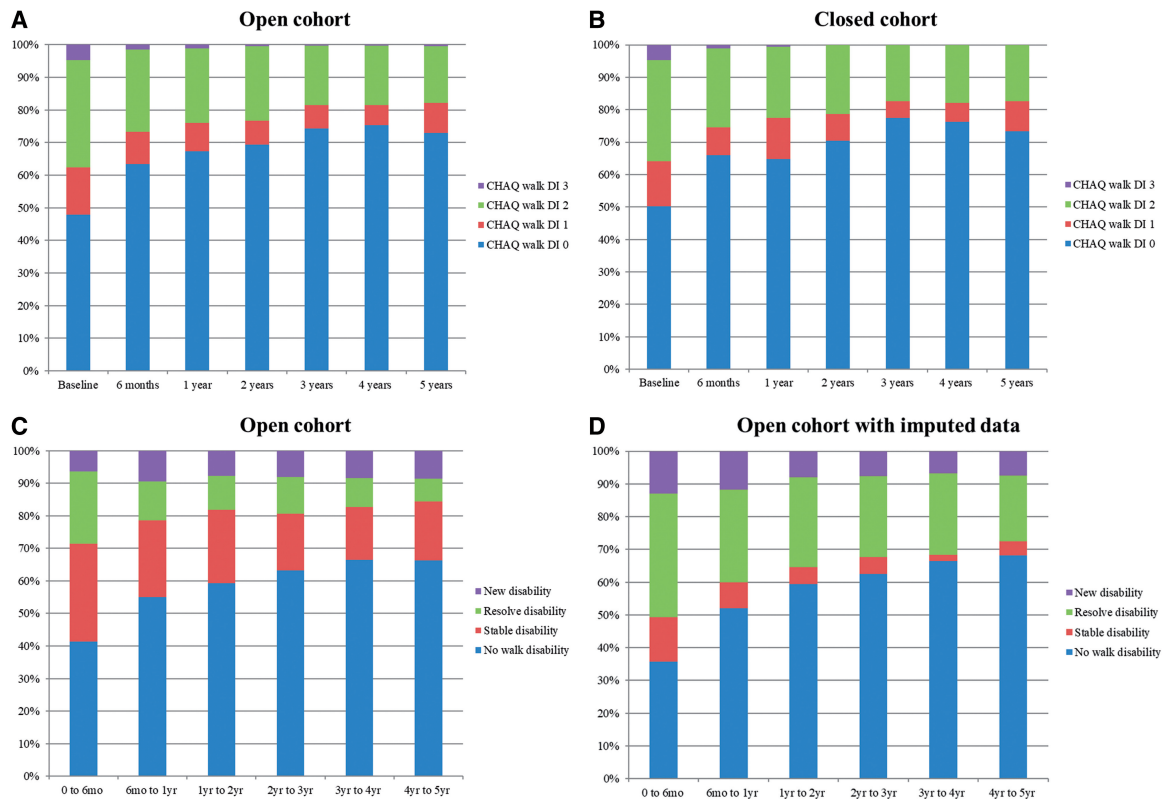
These results suggest that prevalence rates for knee and ankle joint synovitis and joint limitation of motion are high at initial presentation and then stabilize with the initiation of medical therapies. Joint impairments at the hip, subtalar and small foot joints were infrequently observed over the 5-year study and somewhat contrary to previous study findings [2, 9, 12, 13].

Assessments of active and limited joint counts have been shown frequently to underestimate lower limb synovitis relative to more sensitive imaging techniques [23–27]. Expert consensus guidance on imaging in JIA concluded that ultrasound and MRI are superior to clinical examination in the evaluation of joint inflammation [28]. The entity of subclinical synovitis is not currently well understood, but evidence suggesting its presence might predict future JIA relapses [29]. The low prevalence of hip, subtalar and foot synovitis in the present study suggests that the role of imaging requires further consideration.

Persistent synovitis may be problematic at the knee and ankle for a small proportion of children with JIA. This finding is in agreement with previous studies demonstrating that several distinct disease activity courses exist, including moderate increasing and persistent moderate trajectories, which account for ~25% of patients with JIA [30, 31]. This is an important finding

because previous studies have demonstrated that persistent disease activity is associated with radiographic progression and reduced physical function [32, 33]. Ankle joint synovitis appears to be associated with unfavourable disease outcome characterized by failure to achieve remission [34, 35]. The prognosis for lower limb disease activity overall appears to be good, with low a prevalence of lower limb disease activity observed for all lower limb joints after 1 year.

Although the prevalence of walking disability decreased from 52 to 32% at 1-year follow-up, an important finding was that at least mild walking disability affected 25–31% of cases after 1 year despite low prevalence rates of lower limb synovitis. In addition, the majority of those reporting walking disability were in the moderate category, which is indicative of much difficulty in walking or climbing steps. Persistent walking disability also appeared to be problematic for some participants, where 16–22% reported walking disability at two consecutive follow-ups on at least one occasion after 1 year. Together with analyses of transitions and trajectories of walking disability in this cohort, these findings support the theory that walking disability incorporates both reversible and irreversible components, which have been confirmed in studies of overall physical function [3, 16].

Fig. 3 Relative frequencies (percentage of *n*) for walking disability over 5 years

(A) Open cohort (baseline, *n* = 737; 6 months, *n* = 669; 1 year, *n* = 727; 2 years, *n* = 663; 3 years, *n* = 592; 4 years, *n* = 519; 5 years, *n* = 454). (B) Closed cohort (*n* = 173). Light blue: no disability; red: mild walking disability; green: moderate walking disability; purple: severe walking disability. (C and D) Relative frequencies (percentage of *n*) for changes in walking disability state between each successive follow-up for: (C) open cohort (0–6 months, *n* = 502; 6 months–1 year, *n* = 537; 1–2 years, *n* = 544; 2–3 years, *n* = 496; 3–4 years, *n* = 426; 4–5 years, *n* = 374), and (D) open cohort with imputed data. Dark blue: no disability; red: stable disability; green: new disability; purple: resolved disability.

TABLE 2 Transition sequence rates between each walking disability state

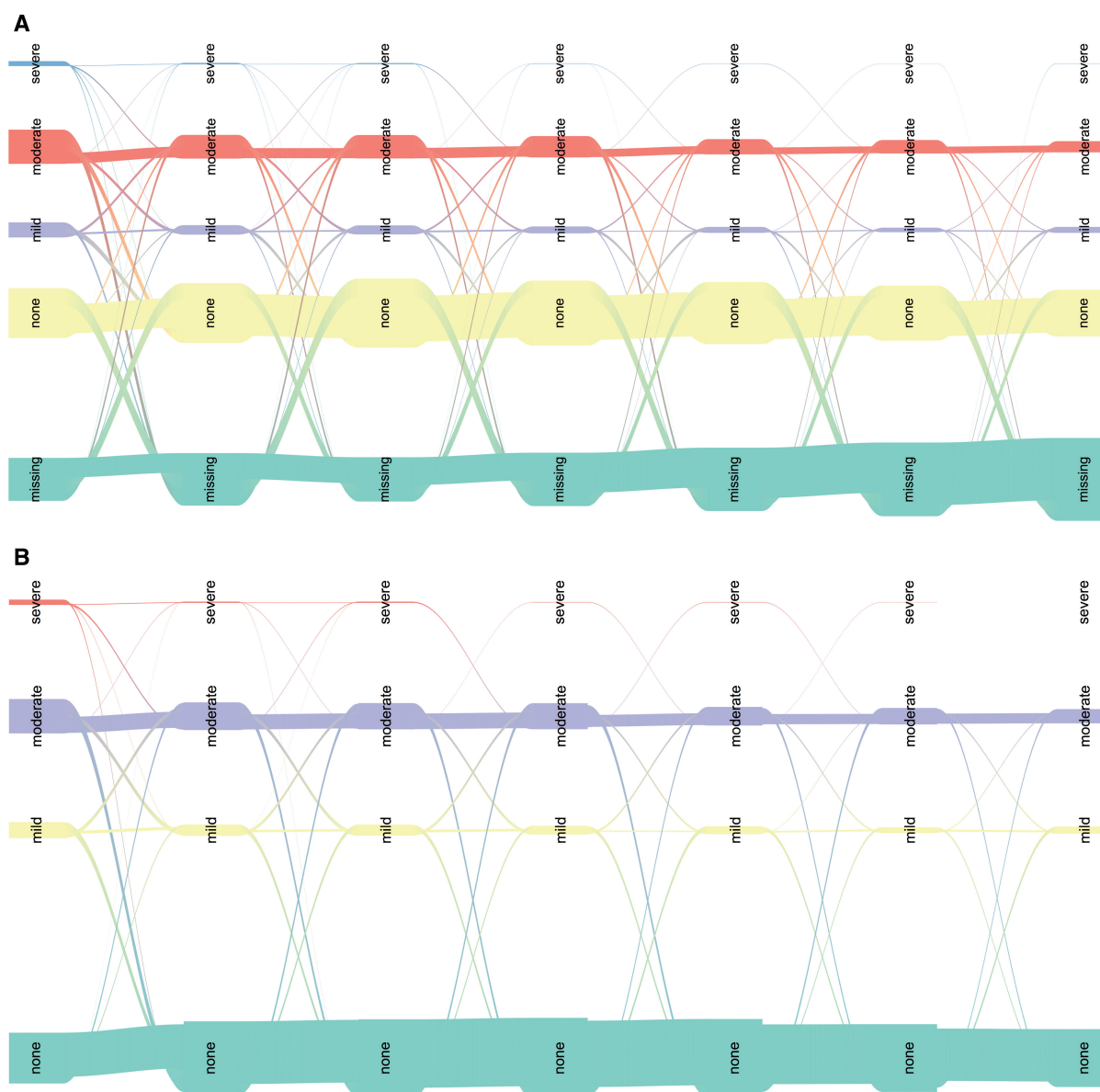
Transitions from	Transitions to				Total (rows)
	→ CHAQ_0	→ CHAQ_1	→ CHAQ_2	→ CHAQ_3	
CHAQ_0 →	2243 (57.4)	128 (3.3)	185 (4.7)	1 (0.03)	2557 (65.4)
CHAQ_1 →	184 (4.7)	81 (2.1)	95 (2.4)	1 (0.03)	361 (9.2)
CHAQ_2 →	283 (7.2)	117 (3.0)	518 (13.3)	12 (0.3)	930 (23.8)
CHAQ_3 →	18 (0.5)	4 (0.1)	30 (0.8)	7 (0.2)	59 (1.5)
Total (columns)	2728 (69.8)	330 (8.4)	828 (21.2)	21 (0.5)	3907

Data are reported as *n* (%). Each row represents the starting sequence of transition from each walking disability state, whereas each column represents the end sequence of transition to each walking state. CHAQ: childhood health assessment questionnaire.

Walking disability in children and young people with JIA is likely to be multifactorial and might be influenced by reduced muscle strength and endurance, impaired motor function, balance and proprioception [36–39]. Gait compensations are often consistent with the avoidance of pain, stiffness and exacerbations of disease, whereby children walk more slowly, less often and less far, followed by deconditioning attributable to reductions in

physical activity [40]. There is strong evidence demonstrating that children with JIA are significantly less active than healthy children [41, 42]. Low levels of physical activity in childhood are not trivial and have been associated with poor body composition (e.g. increased fat, decreased lean muscle, poor bone health) and elevated cardiovascular disease risk in later life [43, 44]. In addition, walking disability may occur as a result of the

Fig. 4 Trajectories for childhood health assessment questionnaire walking disability levels from baseline to 5-year follow-up



The riverplot illustrates the proportion of participants with different levels of walking disability or missing data over time. Each participant's trajectory is illustrated by a single line. The thickness of the line at a node is proportional to the percentage of participants at that level of walking disability. **(A)** Riverplot depicting individual sequential trajectories for CHAQ walking disability ordinal data (open cohort). Thicker lines for no walking disability (none) suggest that a large proportion had no walking disability, whereas relatively few had severe walking disability. **(B)** Riverplot depicting CHAQ walking disability trajectories for the closed cohort ($n = 173$). CHAQ: childhood health assessment questionnaire.

presence of disease-related extra-articular features, such as tenosynovitis, enthesitis in participants with enthesitis-related arthritis or dactylitis in PsA. Data on extra-articular features were not routinely collected for each study participant and therefore were not included in the analyses in the present study.

There was no specific measure of lower limb function collected as part of the CAPS inception cohort study.

As such, we used the CHAQ walking subscale for these analyses. A similar approach has been adopted in adults with RA, where no tool designed specifically to measure lower limb function was available [45]. This novel approach has some advantages in that the CHAQ is commonly administered as part of routine care for JIA, and it has excellent validity, reliability and responsiveness to change [46]. Moreover, normative data are available

from 221 controls for comparison, and this suggests that healthy children will have a mean (s.d.) score of 0 (0.2) on the CHAQ walking subscale [20]. Given the simplicity of the CHAQ walking subscale, which is derived from only two items (Are you/is your child able to: walk outside on flat ground; and climb up five steps?), it is probable that other important aspects of walking (such as the ability to run or walk on uneven ground) are not captured using this subscale. Individual measurement properties of the CHAQ walking disability subscale remain largely unknown; however, previous studies have demonstrated that this subscale has high internal consistency (Cronbach's $\alpha = 0.7\text{--}0.93$) [20, 46].

There are some limitations of the present study concerning the analyses of an open cohort. This cohort was subject to high drop-out rates and missing data because data items were collected as part of routine clinical visits, which might result in selection bias. Moreover, the CAPS recruited from tertiary centres of paediatric rheumatology, which may be more likely to include the most severe cases. A strength of this study is that the potential for selection bias was minimized in three different ways. First, prevalence estimates and transitions for lower limb impairments and walking disability at baseline and over the 5-year follow-up periods were compared by computing open and closed cohort and imputed data (for selected variables). These estimates remained largely consistent across all analyses, suggesting a low risk of selection bias. Second, baseline characteristics between closed and open cohorts were compared and revealed only modest differences for age, symptom duration, PGA and disability score. Third, multiple imputation was adopted according to previously accepted assumptions [21]. Selection bias in patients with full follow-up is concluded to be minimal; however, the possibility of a slight overestimation of lower limb impairments and disability is acknowledged.

Given the length of time between annual follow-ups, it is likely that several fluctuations in joint impairments or walking disability might have taken place between measurements that might not have been captured. Indeed, persistent disease as observed over two follow-ups separated by 1 year might in fact be more reflective of two flares in a joint separated by periods of relative quiescence. Therefore, it is acknowledged that careful interpretation is required for persistence of outcomes over time as presented in this study.

Conclusion

Prevalence rates for lower limb synovitis and walking disability are initially high and then stabilize. The prognosis for lower limb impairments is generally good over 5 years; however, walking disability often persists in spite of low prevalence of lower limb disease activity. This study provides evidence of both persistent walking disability and three distinct trajectories of walking disability, including persistent moderate and fluctuating. The results necessitate further research to clarify the

relationships between lower limb impairments and walking disability in JIA. There might be an unmet need for non-medical strategies designed to prevent and/or resolve persistent walking disability in JIA.

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Supplementary data

Supplementary data are available at *Rheumatology* online.

References

- 1 Manners PJ, Bower C. Worldwide prevalence of juvenile arthritis—why does it vary so much? *J Rheumatol* 2002; 29:1520–30.

- 2 Hendry G, Gardner-Medwin J, Watt GF, Woodburn J. A survey of foot problems in juvenile idiopathic arthritis. *Musculoskeletal Care* 2008;6:221–32.
- 3 Palmisani E, Solari N, Magni-Manzoni S *et al.* Correlation between juvenile idiopathic arthritis activity and damage measures in early, advanced and long-standing disease. *Arthritis Rheum* 2006;55:843–9.
- 4 Ravelli A, Viola S, Ruperto N *et al.* Correlation between conventional disease activity measures in juvenile chronic arthritis. *Ann Rheum Dis* 1997;56:197–200.
- 5 Hemke R, Nusman CM, van der Heijde DMFM *et al.* Frequency of joint involvement in juvenile idiopathic arthritis during a 5-year follow-up of newly diagnosed patients: implication for MR imaging as outcome measure. *Rheumatol Int* 2015;35:351–7.
- 6 Bazso A, Consolaro A, Ruperto N *et al.* Development and testing of reduced joint counts in juvenile idiopathic arthritis. *J Rheumatol* 2009;36:183–90.
- 7 Foster HE, Eltringham MS, Kay LJ *et al.* Delay in access to appropriate care for children presenting with musculoskeletal symptoms and ultimately diagnosed with juvenile idiopathic arthritis. *Arthritis Rheum* 2007;57:921–7.
- 8 Hartmann M, Kreuzpointner F, Haefner R *et al.* Effects of juvenile idiopathic arthritis on kinematics and kinetics of the lower extremities call for consequences in physical activity recommendations. *Int J Paediatr* 2010;2010:835984.
- 9 Dekker M, Hoeksma AF, Dekker JHM *et al.* Strong relationships between disease activity, foot-related impairments, activity limitations and participation restrictions in children with juvenile idiopathic arthritis. *Clin Exp Rheumatol* 2010;28:905–11.
- 10 Broström E, Haglund-Akerlind Y, Hagelbers S, Cresswell AG. Gait in children with juvenile chronic arthritis. *J Rheumatol* 2002;31:317–23.
- 11 Scholes S, Mindell J. Health survey for England 2012: physical activity in children. London: The Health and Social Care Information Centre, 2013.
- 12 Flatø B, Lien G, Smerdel A *et al.* Prognostic factors in juvenile rheumatoid arthritis. *J Rheumatol* 2003;30:386–93.
- 13 Jacobsen FS, Crawford AH, Broste S. Hip involvement in juvenile rheumatoid arthritis. *J Pediatr Orthop* 1992;12:45–53.
- 14 McErlane F, Beresford MW, Baildam EM *et al.* Validity of a three-variable juvenile arthritis disease activity score in children with new-onset juvenile idiopathic arthritis. *Ann Rheum Dis* 2013;72:1983–8.
- 15 Damasio MB, Malattia C, Martini A, Tomà P. Synovial and inflammatory diseases in childhood: role of new imaging modalities in the assessment of patients with juvenile idiopathic arthritis. *Pediatr Radiol* 2010;40:985–98.
- 16 Magni-Manzoni S, Pistorio A, Labò E *et al.* A longitudinal analysis of physical functional disability over the course of juvenile idiopathic arthritis. *Ann Rheum Dis* 2008;67:1159–64.
- 17 Hyrich KL, Lal SD, Foster HE *et al.* Disease activity and disability in children with juvenile idiopathic arthritis one year following presentation to paediatric rheumatology. Results from the childhood arthritis prospective study. *Rheumatology* 2010;49:116–22.
- 18 Petty RE, Southwood TR, Manners P *et al.* International League of Associations for Rheumatology classification of juvenile idiopathic arthritis: second revision, Edmonton, 2001. *J Rheumatol* 2004;31:390–2.
- 19 Giannini EH, Ruperto N, Ravelli A *et al.* Preliminary definition of improvement in juvenile arthritis. *Arthritis Rheumatol* 1997;40:1202–9.
- 20 Nugent J, Ruperto N, Grainger J *et al.* The British version of the childhood health assessment questionnaire (CHAQ) and the child health questionnaire (CHQ). *Clin Exp Rheumatol* 2001;19:S163–7.
- 21 Shoop-Worrall SJ, Verstappen SM, Baildam E *et al.* How common is clinically inactive disease in a prospective cohort of patients with juvenile idiopathic arthritis? The importance of definition. *Ann Rheum Dis* 2017;1391–88.
- 22 Gabadinho A, Ritschard G, Müller NS, Studer M. Analyzing and visualizing state sequences in R with TraMineR. *J Stat Softw* 2011;40:1–37.
- 23 Haslam KE, McCann LJ, Wyatt S, Wakefield RJ. The detection of subclinical synovitis by ultrasound in oligoarticular juvenile idiopathic arthritis: a pilot study. *Rheumatology* 2010;49:123–7.
- 24 Rooney ME, McAllister CA, Burns JF. Ankle disease in juvenile idiopathic arthritis: ultrasound findings in clinically swollen ankles. *J Rheumatol* 2009;36:1725–9.
- 25 Nistala K, Babar J, Johnson K *et al.* Clinical assessment and core outcome variables are poor predictors of hip arthritis diagnosed by MRI in juvenile idiopathic arthritis. *Rheumatology* 2007;46:699–702.
- 26 Hendry GJ, Gardner-Medwin J, Steultjens MP *et al.* Frequent discordance between clinical and musculoskeletal ultrasound examinations of foot disease in juvenile idiopathic arthritis. *Arthritis Care Res* 2012;64:441–7.
- 27 Lanni S, Bovis F, Ravelli A *et al.* Delineating the application of ultrasound in detecting synovial abnormalities of the subtalar joint in juvenile idiopathic arthritis. *Arthritis Care Res* 2016;68:1346–53.
- 28 Colebatch-Bourn AN, Edwards CJ, Collado P *et al.* EULAR-PRReS points to consider for the use of imaging in the diagnosis and management of juvenile idiopathic arthritis in clinical practice. *Ann Rheum Dis* 2015;74:1946–57.
- 29 Silva VBME, Mitraud SAV, Furtado RNV, Natour J, Terrier MT. Preliminary prospective study of ultrasonography in patients with juvenile idiopathic arthritis in clinical remission: subclinical synovitis may predict flare? *Arthritis Rheum* 2013;65:S125–6.
- 30 Nordal E, Rypdal V, Christoffersen T *et al.* Incidence and predictors of uveitis in juvenile idiopathic arthritis in a Nordic long-term cohort study. *Pediatr Rheumatol Online J* 2017;15:66.
- 31 Berard RA, Tomlinson G, Li X *et al.* Description of active joint count trajectories in juvenile idiopathic arthritis. *J Rheumatol* 2014;41:2466–73.
- 32 Selvaag AM, Flatø B, Dale K *et al.* Radiographic and clinical outcome in early juvenile rheumatoid arthritis and juvenile spondyloarthritis: a 3-year prospective study. *J Rheumatol* 2006;33:1382–91.

- 33 Mason T, Reed AM, Nelson AM, Thomas KB. Radiographic progression in children with polyarticular juvenile rheumatoid arthritis: a pilot study. *Ann Rheum Dis* 2005;64:491–3.
- 34 Esbjörnsson AC, Aalto K, Broström EW *et al.* Ankle arthritis predicts polyarticular disease course and unfavourable outcome in children with juvenile idiopathic arthritis. *Clin Exp Rheumatol* 2014;33:751–7.
- 35 Guzman J, Henrey A, Loughin T *et al.* Predicting which children with juvenile idiopathic arthritis will have a severe disease course: results from the ReACCh-Out cohort. *J Rheumatol* 2017;44:230–40.
- 36 Baydogan SNA, Tarakci E, Kasapcopur O. Effect of strengthening versus balance-proprioceptive exercises on lower extremity function in patients with juvenile idiopathic arthritis. *Am J Phys Med Rehabil* 2015;94:417–28.
- 37 Houghton KM, Guzman J. Evaluation of static and dynamic postural balance in children with juvenile idiopathic arthritis. *Pediatr Phys Ther* 2013;25:150–7.
- 38 Van der Net J, van der Torre P, Engelbert RHH *et al.* Motor performance and functional ability in preschool- and early school-aged children with Juvenile Idiopathic Arthritis: a cross-sectional study. *Pediatr Rheumatol Online J* 2008;6:2.
- 39 Broström E, Hagelberg S, Haglund-Akerlind Y. Effect of joint injections in children with juvenile idiopathic arthritis: evaluation by 3D-gait analysis. *Acta Paediatr* 2004;93:906–10.
- 40 Singh-Grewal D, Schneiderman-Walker J, Wright V *et al.* The effects of vigorous exercise training on physical function in children with arthritis: a randomized controlled, single-blinded trial. *Arthritis Rheum* 2007;57:1202–10.
- 41 Lelieveld OTHM, Armbrust W, van Leeuwen MA *et al.* Physical activity in adolescents with juvenile idiopathic arthritis. *Arthritis Care Res* 2008;59:101379–84.
- 42 Lelieveld OTHM, Armbrust W, van Leeuwen MA *et al.* Physical activity in children with juvenile idiopathic arthritis compared to controls. *Pediatr Rheumatol Online J* 2016;14:42.
- 43 Bohr A-H, Fuhlbrigge RC, Pedersen FK, de Ferranti SD, Müller K. Premature subclinical atherosclerosis in children and young adults with juvenile idiopathic arthritis. A review considering preventive measures. *Pediatr Rheumatol Online J* 2016;14:3.
- 44 Coulson EJ, Ng WF, Goff I, Foster HE. Cardiovascular risk in juvenile idiopathic arthritis. *Rheumatology* 2013; 52:1163–71.
- 45 van der Leeden M, Dahmen R, Ursum J *et al.* Prediction of walking disability by disease-related factors in patients with rheumatoid arthritis. *J Rehabil Med* 2010; 42:506–10.
- 46 Singh G, Athreya BH, Fries JF, Goldsmith DP. Measurement of health status in children with juvenile rheumatoid arthritis. *Arthritis Rheumatol* 1994;37: 1761–9.